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Thin lenses

The refractive nature of light is what allows lenses made of glass or plastic enlarge or shrink images. The formula for thin lenses

thin lens formula

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

assumes that the lens is much thinner than its diameter. The error introduced by the thickness of the lens can be ignored.

f is the focal length of the lens. It is often given in centimeters although the SI unit for distance is meters. Usually in working with lenses you can keep your distances in terms of cm and not need to convert to meters. ALWAYS BE CAREFUL WHEN WORKING WITH NON-SI UNITS.

1 The focal length of a lens is one half the radius of curvature (which is what the radius of the lens would be if it were a full sphere)

2. The focal length can be easily determined with a convex lens by holding above a sheet of paper in the sunlight. The image of the sun will appear on the paper when the paper is held a distance from the lens a distance equal to the focal length of the lens.

3. The focal length of a convex lens is a positive number and the focal length of a concave lens is a negative number

4. The focal length of a concave mirror is a positive number and the focal length of a convex mirror is a negative number.

5. A convex lens can produce a real image (one that can be projected onto a screen) and a concave mirror can produce a real image. A concave lens and a convex

mirror can only produce virtual images (ones that cannot be projected onto a screen)

6. Only lenses and mirrors with positive focal lengths can give real images

The above are in red and enlarged so that you will realize that you need to memorize them immediately. Concepts in physics build on each other and you will find yourself in trouble quickly if you do not internalize the building blocks as soon as they are presented to you.

In the thin lens formula, d_o and di stand for the object distance and the image distance respectively. When someone takes a picture of you, the distance you are standing from the lens of the camera is the object distance and the distance from the lense of the camera to the film is the image distance.

Extra credit opportunity (1 free daily quiz 100)
Bring a package of 1/4 inch grid graph paper, a straight edge, a green pencil,and a red pencil. You must bring this the first day of class to receive credit.

38.15. A converging lens is the same as a convex lens

Drawing these rays is called “Geometric Optics” and gives a very accurate description of the image formation, especially when graph paper is used.

The rules (my language)

definition:
Focal length of first surface: The focal length of the curved surface that the ray of light coming from the object first strikes. For a convex lens this surface has its focal point on the side opposite the object. FOr a concave lens, this first surface has its focal point on same side of the lens as the object.

Focal length of second surface: The focal length of the second surface for a convex lens is on the same side of the lens as the object. THe focal length of the second surface for a concave lens is on the side opposite the object.

Principle or Central Axis. THis is a line (usually dotted) that runs from the base of the object through the very center of the lens and continues on through the other side

Ray One: (always make this ray red). This ray starts at the upper tip of the object and runs parallel to the Principle Axis until it strikes the center of the lens. It then goes through the focal point of the first surface. This line theoretically goes in both directions infinitely. In particular, when the object is located inside the focal length you will need to draw it backwards.

Ray 2: (Make this line green) This line starts at the tip of the object and FIRST GOES THROUGH THE FOCAL LENGTH OF THE SECOND SURFACE. When it gets to the lens however, draw it as a dotted line to the actual focal length of the second surface (this will make it less confusing, trust me). When this line strikes the center of the lens (goes form being a solid line to a dotted line), it then travels parallel to the Central Axis (as a solid line)

The image will appear where the two rays intersect.

Ray 3: This ray serves as a check or in the case that the object is placed at the focal point it is necessary. It is also used for mirrors (since a mirror only has one focal point). Draw this line in pencil or black or blue ink. Ray 3 simply starts at the tip on the object and goes straight through the very center (both vertically and horizontally) of the lens. The three rays should intersect at the point where the tip of the image will appear.

A real good thing to know about convex lenses and concave mirrors.

If the object is held at two times the focal length of the lens or mirror (at the radius of curvature), then the image will be <u>real</u> and it will appear at exactly the same distance from the lens. In other words, the image distance will equal the object distance. The image produced by the convex lens will be on the opposite side of the lens and the image produced by the mirror will be on the same side as the object.

With a convex lens and a concave mirror, the image will be real as long as the object is held outside the focal length but will become *virtual* when the object is placed inside the focal length

38.16 Use the thin lens formula. A converging lens (convex) has a positive focal length. You will get a negative number for the image distance. This means that the image is inverted (upside down).

MAGNIFICATION IS EQUAL TO

$$magnification = \square \frac{d_i}{d_o} = \frac{image\_size}{object\_size}$$

38.17 Notice that the answer gives object distance 1 (outside focal length) and 2 (inside focal length). When you place an object inside the focal length of a convex lens you are using the lens as magnifying glass (try it)

$$magnification = \square \frac{d_i}{d_o} = \frac{image\_size}{object\_size}$$

$$8 = \frac{d_i}{d_o}$$

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

You are given two equations in two unknowns. A common problem in physics. You do not know d_o or d_i. But you know *f* and you know the relationship between d_o and d_i. A very important law is the for every unknown you have you need one equation (pretty nice of God to make it that simple).

NOW, YOU SEE WHY IT IS IMPORTANT TO MEMORIZE BASIC CONCEPTS BECAUSE IF YOU DID NOT KNOW THE LENS FORMULA OR THE FORMULA FOR MAGNIFICATION YOU WOULD NOT KNOW THE FIRST PLACE TO LOOK FOR THESE TWO EQUATIONS OR EVEN KNOW THAT YOU NEEDED THEM.

38.18. First of all you know that it is a convex lens since a concave lens can never give a real image. you are given d_i and M. You need to solve for d_o and *f*.

38.19 A diverging lens is the same as a concave lens (it diverges the light). Therefore, its focal length is a negative number. Use the thin less formula.

38.20. (A) Us e the thin lens formula. When they mean "very great" they essentially mean infinity. recall that as the number in the denominator approaches infinity, the number approaches zero. (it is not really legal to say that 1 over infinity is equal to zero)

38.21. You are given the magnification and the fact that the image is cast onto a screen. Therefore it is a real image and the lens must be convex and thus have a positive focal length. You are given the magnification. This means that the image distance is 24 times the object distance. So there is one formula. YOu also know that the image distance plus the object distance is equal to 12.5 m. From this you have the information to determine the focal length and the image and or object distance.

38.22 Use the lens makers equation $\frac{1}{f} = (n - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

R is the radius of each surface, for a plane this radius is equal to infinity, therefore $1/R_2 = 0$

38.23 Use the lens makers equation and the formula for magnification

38.24. Us the lens makers equation for air (part a). Then use the fact that its relative index of refraction when placed in water is 1.5/1.33. (See example problem 38.11) for part b.

38.25 Use the lensmakers equation to get the focal length. convert the focal length from cm to meters. The focal length in diopters is just the inverse of the focal length in meters (1/0.20)

38.26 Find the focal length of the first combination (the 16 cm and the -23 cm focal length). Recall that the radius is two times the focal length. Now use this composite lens as on the lenses used in combination with the -12 cm lens. Have fun!!

NEITHER THE AP EXAM OR THE IB EXAM ARE CONCERNED WITH THE LENSMAKERS FORMULA ALTHOUGH I THINK ONE OF THEM HAD A PROBLEM ON IT ONE YEAR. IF THAT WAS THE CASE, THE FORMULA WAS GIVEN WITH THE PROBLEM. SO WHILE IT IS IMPERATIVE THAT YOU LEARN THE THIN LENS FORMULA, THE FORMULA(S) FOR MAGNIFICATION, AND THE SIGN CONVENTIONS FOR CONVEX AND CONCAVE LENSES AND MIRRORS (YOU SHOULD BE HAVING DREAMS ABOUT THEM), ANY QUIZ OR TEST PROBLEM I GIVE YOU WITH THE LENSMAKERS EQUATION WILL INCLUDE THE ACTUAL FORMULA